RULE 1.26

CLAIMS

What is claimed is:

11. ~~1)~~ Multicycle integration focal plane array (MIFPA), linear or area, which is a new type of electronic apparatus, and, unlike the existing FPA composed of a single-cycle integrator, is composed of

a) a correlated multicycle integrator that can be incorporated into an integrated circuit for each pixel of the MIFPA;

b) signal **10** being modulated either passively by a mechanical or electronic chopper **11** or actively by a pulsed light source **15**;

c) background (and/or dark current) **14** being unmodulated;

d) the input current **17** comprising the modulated signal and unmodulated background being fed to an integrator;

e) so that the signal being accumulated while the background being cancelled;

f) so that the signal to noise ratio and dynamic range can be greatly improved.

12 ~~2)~~ The method of using MIFPA for the detection of extremely weak signals for imaging, spectroscopy, and spectroscopic imaging, which comprises the following steps:

a) a lens or lens system **12** is placed between the scene or object **10** for imaging, spectroscopy, or spectroscopic imaging and the multicycle integration focal plane array (MIFPA) **13**, composed of either one- or two-dimensional of photodetectors **16**, where the image and or spectroscopic signal is collected;

b) a passive optical modulator **11**, which can be a mechanic chopper, an electric-optical switch, a polarizer, or other devices, is placed between the scene or object **10** and the FPA **13** to modulate the photon flux from the aforesaid scene or object **10** for imaging, spectrum, or spectroscopic imaging;

c) or an active modulator, such as a pulsed light source **15**, is used to generate modulated image and/or spectroscopic signals;

d) when the modulator is on in one phase ($\phi 1$ in the figure), the current generated by the detector **17** is the signal photocurrent I_s from object or scene **10**, plus the DC background current I_b from the radiation **14** not modulated;

e) when the radiation from the imaging target is blocked by the modulator in another phase $\phi 2$, only the DC I_b is present;

f) by controlling the correlated multicycle integrator synchronically with the modulation control signal, using the same correlated controller **28**, the integrator **30** charges the capacitor with the signal and background currents in $\phi 1$, but discharges it with background current only in $\phi 2$;

g) so that the output of **30** is accumulated signal current I_s only (plus the shot noise that is not avoidable);

h) so that the aforesaid accumulated signal current I_s can be fed to any commercial amplifier and/or display for image, spectrum, or spectral imaging using conventional imaging and/or spectroscopic methods.

13 ~~3~~) Lock-in multicycle integration focal plane array (LI-MIFPA), linear or area, which is a special type of multicycle integration focal plane array (MIFPA), linear or area, comprising:

a) all the features of claim 1;

b) with the signal accumulation phase $\phi 1$ and background cancellation phase $\phi 2$ strictly equal in time.

14 ~~4~~) The method of using LI-MIFPA for the detection of extremely weak signals for imaging, spectroscopy, and spectroscopic imaging, which comprises the following steps:

a) all the steps in claim 2;

b) with the signal accumulation phase $\phi 1$ and background cancellation phase $\phi 2$ strictly equal in time.

15 ~~5)~~ Gated multicycle integration focal plane array (G-FPA), linear or area, which is a special type of multicycle integration focal plane array (MIFPA), linear or area, comprising:

a) all the features of claim 1;

b) with $\phi 1$ lasting an interval of $\alpha\tau$, $\phi 2$ lasting an interval of 0 time, and a new phase $\phi 3$ lasting an interval of $(1-\alpha)\tau$

c) wherein during phase $\phi 3$ the integrator **30** is turned off;

d) wherein $\alpha \ll 1$, or $(1-\alpha)\tau \gg \tau$.

16 ~~6)~~ The method of using G-MIFPA for the detection of extremely weak signals for imaging, spectroscopy, and spectroscopic imaging, under the condition that the signal duty cycle α is extremely small while the background current is not extremely large, namely $\alpha \ll 1$, while I_s not $\ll I_b$, as in some types of IR fluorescence spectroscopy using nano-second pulse laser excitation, which comprises:

a) all the steps in claim 2;

b) with $\phi 1$ lasting an interval of $\alpha\tau$, $\phi 2$ lasting an interval of 0 time, and a new phase $\phi 3$ lasting an interval of $(1-\alpha)\tau$

c) wherein during phase $\phi 3$ the integrator **30** is turned off;

d) wherein $\alpha \ll 1$, or $(1-\alpha)\tau \gg \tau$.

17 ~~7)~~ Gated lock-in multicycle integration focal plane array (GLI-MIFPA), linear or area, which is a special type of multicycle integration focal plane array (MIFPA), linear or area, comprising:

a) all the features of claim 1;

b) with $\phi 1$ lasting an interval of $\alpha\tau$, $\phi 2$ lasting an equal interval of $\alpha\tau$, and a new phase $\phi 3$ lasting an interval of $(1-2\alpha)\tau$

c) wherein during phase $\phi 3$ the integrator **30** is turned off;

d) wherein $\alpha \ll 1$, or $(1-2\alpha)\tau \gg \tau$.

18 ~~8~~ The method of using GLI-MIFPA for the detection of extremely weak signals for imaging, spectroscopy, and spectroscopic imaging, under the condition that the signal duty cycle α is extremely small and the background current is extremely large, namely $\alpha << 1$, and $I_s << I_b$, as in some types of IR fluorescence spectroscopy using nano-second pulse laser excitation, which comprises :

a) all the steps of claim 2;

b) with $\phi 1$ lasting an interval of $\alpha\tau$, $\phi 2$ lasting an equal interval of $\alpha\tau$, and a new phase $\phi 3$ lasting an interval of $(1-2\alpha)\tau$

c) wherein during phase $\phi 3$ the integrator 30 is turned off;

d) wherein $\alpha << 1$, or $(1-2\alpha)\tau >> \tau$.

REPLACED BY AMENDMENT OF 5/25/04

7/18/02

CLAIMS

1) A new type of focal plane array — multicycle integration focal plane array (MIFPA), linear or area, which, unlike the existing FPA of single-cycle integration, utilizes three additional MOS switches (M1, M2, and M3 of fig. 1) and one additional capacitance (C1 of fig. 1) for each pixel to perform on-chip multicycle integration.

REPLACED BY CLAIMS FILED 25 MAY 04

2) Applications of MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.

3) Three operational modes of MIFPA — lock-in (LI-), gated (G-), and gated lock-in (GLI-) modes.

4) A new type of focal plane array — lock-in multicycle integration focal plane array (LI-MIFPA), linear or area, which possesses the following features:

a) it uses an active or passive modulator to modulate the signal;

b) it does not modulate dark and/or background current;

c) it uses a correlated multicycle integrator for each pixel, so that the signal current is accumulated while the background and/or dark current is cancelled;

d) the integration time of the LI-MIFPA can be many orders longer than that of the existing FPA technology;

e) therefore, the signal to noise ratio, dynamic range, and low frequency or $1/f$ noise of the LI-MIFPA can be improved by many orders in comparison with the existing FPA technology.

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5) Applications of LI-MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.

6) A new type of focal plane array — gated multicycle integration focal plane array (G-MIFPA), linear or area, which has the same multicycle correlated integrator for each pixel as the LI-MIFPA, is programmed to operate in the gated mode, and possesses the following features:

a) it uses a pulsed light source to generate a repetitive signal (as in the case of IR fluorescence spectroscopy using nano-second pulse laser excitation);

b) the G-MIFPA is used when the number of integrated signal electrons is many orders smaller than that of the background and/or dark current electrons $\alpha I_s << I_b$, but αI_s is not $<< I_b$;

c) in G-MIFPA the direction of integration of the correlated multicycle integrator does not change as in the LI-MIPFA; The integrator is turned on by a trigger signal from the gate control circuit to integrate the signal photocurrent pulse, and turned off after a certain increment of time;

d) the integration time of the G-MIFPA can be many orders longer than that of the existing FPA technology;

e) therefore, the signal to noise ratio, dynamic range, and low frequency or $1/f$ noise of the G-MIFPA can be improved by many orders in comparison with the existing FPA technology.

7) Applications of G-MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.

8) A new type of focal plane array — gated lock-in multicycle integration focal plane array (GLI-MIFPA), linear or area, which has the same multicycle correlated integrator for each pixel as the LI-MIFPA, is programmed to operate in the gated lock-in mode, and possesses the following features:

a) it uses a pulsed light source to generate a repetitive signal (as in the case of LWIR spectroscopy using nano-second pulse laser excitation);

b) the GLI-MIFPA is used when the signal is not only short, but is also associated with a much stronger background ($\alpha \ll 1$, $I_s \ll I_b$);

c) in GLI-MIFPA, the correlated multicycle integrator goes through three phases (Fig. 5.b). In $\phi 1$, which lasts $\alpha\tau$, the integrator integrates both the signal pulse and strong background currents. In $\phi 2$, which has the same duration as $\phi 1$, the integrator reverses its direction of integration, and cancels the background of $\phi 1$. In $\phi 3$, which lasts much longer than $\phi 1$ or $\phi 2$, the integrator is turned off.

d) the GLI-MIFPA combines the advantage of the G-mode — reduction of the on-time of the integrator to increase the integration time — and that of the LI mode — cancellation of background to increase the integration time;

e) therefore, the signal to noise ratio, dynamic range, and low frequency or $1/f$ noise of the G-MIFPA can be improved by many orders in comparison with the existing FPA technology.

9) Applications of GLI-MIFPA — to detect extremely weak signals for imaging, spectroscopy, and spectroscopic imaging.

10) A new device — correlated multicycle integrator (comprising of one operational amplifier or source follower and four MOS switches), which can be programmed to control the MIFPA to operate in lock-in (LI-), gated (G-), or gated lock-in (GLI) mode.